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IX.—*On the Natural History of the Cingalese Pearl Oyster and on the Production of Pearls. Derived from* Dr. KELAART'S "Introductory Report on the Natural History of the Pearl Oyster of Ceylon," *and from* "Die echten Perlen, ein Beitrag zur .... Geschichte derselben," by Dr. KARL MÖBIUS, Hamburgh, 1857. By W. S. DALLAS, F.L.S.

WITHOUT following Dr. Möbius through his long and interesting account of the Pearl-fisheries and the commerce in pearls from the earliest periods to the present time, we may take the fact that the annual importation of pearls into France and England alone averages in value between £40,000 and £50,000 as a convincing proof of the importance of the traffic in these articles of luxury. Moreover, when we consider that one of the principal existing stations for this fishery is upon the coast of the British Island of Ceylon, and that, in accordance with immemorial custom, the Government of the island has a *direct* interest in the prosperity of the fishery, which is still carried on in the same fashion as that by which the celebrated pearl of Cleopatra was obtained from the deep,—it will readily be admitted that it is a matter of no small importance to the Government of Ceylon to ascertain whether the pearl-oyster banks may not be rendered more productive by a better system of management. Is it not possible that these valuable Mollusks may be treated somewhat in the same way as our so-called 'Native' Oysters, so as not only to protect them from injurious influences, but also to enable them to be procured by a more economical process than that primitive one of human divers, which still prevails wherever the pearl-fishery exists? To settle this important point, the Governor of Ceylon commissioned Dr. Kelaart, in March last, to investigate the natural history of the Pearl Oyster, and we have now before us that gentleman's first report upon the subject. His investigations were carried on by keeping the animals partly in tubs and other vessels, partly in perforated wooden boxes and old canoes sunk at various depths in the sea, and partly in aquaria with glass fronts, to the usefulness of which in facilitating observations Dr. Kelaart bears strong testimony; and he also, apparently unexpectedly, obtained great "facilities of observation amongst the small beds of oysters found in the inner harbour of Trincomalee. They are found of all ages and sizes, at various depths and on different kinds of banks; so that," adds Dr. Kelaart, "no naturalist has perhaps ever had the same opportunities of observing the habits of the Pearly mollusk as I have at present."

The Ceylonese Pearl Oyster is the *Mytilus margaritiferus*, Linn., the *Meleagrina margaritifera* of Lamarck, which appears to be common to all the shores of the Indian and Pacific Oceans, from the Red Sea and the east coast of Africa in the west, to California, Panama and Chili in the east. The Ceylonese shells belong to that variety of the species described by Leach under the name of *Avicula radiata*; indeed, Templeton seems inclined to regard it as a distinct species. On the other side of the Isthmus of Panama, in the Gulf of Mexico, and wherever Pearl Oysters occur on the west coast of America, the species appears to be the *Avicula squamulosa*, Lamk. The anatomy of the animal is described by Dr. Kelaart as follows:—

"The free border of the mantle lining each valve dips downwards to meet a similar veil on the opposite side, thus forming a kind of double-fringed veil. The one set of tentacular fringe, in immediate contact with the shell, is composed of hairy tentacles, looking horizontally forwards; the other, about $\frac{3}{8}$ths of an inch apart from the former, and lining the edge of the mantle from side to side, looks downwards, and dovetails with the tentacles of the opposite flap of the mantle. These tentacles consist of a series of long and short flat filaments—the long ones having lateral filamentous projections. The tentacles are exceedingly sensitive; and one would almost give them the power of seeing; for not only the touch of a feather, but the approach of one, when the animal is lively and in good health, makes them draw forwards, and perfectly shut out the intruder. As these molluscs have no organ of sight, I have no doubt that the delicate nerves which are distributed through the mantle and its tentacular processes, possess in some degree the sense answering to vision in other animals, as well as of touch; for an oyster will be observed rapidly to close its valves on the approach to the aquarium of a lighted candle, or even the approach of a hand, or the shadow of a person, near the glass sides of a vessel in which it is confined. I should not in a popular Report advert to this physiological subject, but that the senses of the oyster have a great deal to do with its habits, not only in the aquarium, but also in its native bed. Were it not for these delicate fringes surrounding the mantle, the softer parts of the oyster would easily become the food of a host of carnivorous creatures abounding in the sea; and many more pearls would drop out of the shell than do now with such sentinels at the entrance of its external rim. The mantle is the only organ the animal has for the formation of the shell, the increase of the lateral dimensions of which, and the formation of the pearly nacre, and pearls, depend upon the condition of this important investment. If it is injured, the pearly matter is not secreted in such abundance over the shell, or if, by some cause, it becomes retracted, the shell does not grow rapidly, and the mother-of-pearl lining is jagged at the edge, and is not of the usual brilliant colour. However, its temporary retraction facilitates the ingress of sand and other irritating particles, which doubtless become the nuclei of many a pearl, as will be hereafter observed. The fore part of the mantle is coloured and rayed like the shell. The colouring matter is secreted by glands found in these parts. This glandular secretion serves the purpose of increasing the lateral and longitudinal dimensions of the shell. It is after this is deposited, that the pearly secretion (nacre) is applied to the inner wall of the shell, which, concreting or solidifying, increases its thickness. The pearly fluid is secreted by nearly the whole external surface of the mantle. It will be thus clearly understood that when a grain of sand or the larva of an insect is introduced between the mantle and shell, it will become covered over with the pearly secretion; which, always going on, is augmented at that part where the foreign matter lies. This phænomenon I have detected, with the aid of the microscope, in its very earliest stage.

"About 1¼ inch from the rim of the shell, is seen a pair of gills, like four segments of a circle, or semilunar combs, stretching transversely from one side to the other, the convexity looking forwards. There is a vacant space between the concave surface of the gills and the body of the oyster. The adductor muscle, called 'gristle,' is now seen, covered over with a delicate membrane. This muscle is attached to the inner surface of both the shells. On one side (the left, when the oyster is placed with the hinge next the observer) is seen a short, conical, tubular, sharp-pointed prolongation; this is the terminal end of the intestines: it looks like a sharp-pointed claw. The intestine is short; leaving the stomach, it winds round the adductor muscle, and terminates, as I have just remarked, on the side opposite to where the mouth is placed. There is always an unclosed space between the edges of the mantle, when the tentacles are brought together, admitting of the free passage of excrementitious matter; and it was through the same opening between the mantle, that I observed, on one occasion, the ova escape, in a cloudy stream which continued to pass into the water for nearly fifteen minutes. I failed to detect the immediate part of the animal through which the ova found their exit; and I have not been able to detect a regular oviduct. The ovaria, when distended with ova, cover nearly the whole of the stomach, heart and liver, and project even on the conical cæcal process of the stomach, and also on the base of the foot. The stomach is very small, placed in the centre of the liver; the œsophagus is very narrow, scarcely admitting a moderate-sized probe; it is about 3 lines long. The mouth, situated near the hinge, behind the foot and byssus, is a horizontal slit, of about 3 lines in length, in the duplicature of the lower pair of labial palps. These palps are large, broad, truncated anteriorly, and rounded on the sides; the inner surface plaited, or rather grooved. The sense of feeling or touch is, no doubt, by this rugose structure, greatly increased. The palps serve the animal as organs of touch, if not of taste; they also serve to collect food, and give the animal the power of rejecting indigestible particles of matter, or such substances as might prove injurious."

The food of the Pearl Oyster, according to Dr. Kelaart, consists of minute Algæ, Infusoria, and Foraminifera. *Diatomaceæ* and other microscopic organisms are found growing abundantly on the outer surface of the shell; "so that the oyster may be said to carry on its back the food upon which it lives."

The Pearl Oyster of Ceylon is of small size, the shells usually measuring only 2½–3 inches in their largest diameter; but it nevertheless takes six or seven years in reaching maturity. Like our Common Oyster, it appears to have the sexes distinct; at least, although the majority of the specimens of all ages are found to contain ova, a few are met with bearing "spermatozoa or seminal fluid, in organs similar to those which, in a larger number of individuals, contain ova." Even the native divers are of opinion that there are *male and female* Pearl Oysters; and Dr. Kelaart justly states that "the important part which the male oyster must play in the formation of banks of oysters is self-evident, if it can be clearly established that the ova absolutely require the vivifying influence of a male fluid," or, rather, that this fluid is always secreted in the sexual organs of male individuals. At the same time he observes, that he has not seen more than three or four individuals with this milky fluid in a hundred oysters; and if this should prove to be the normal proportion between the sexes, the importance of recognizing and preserving the males would become still more evident. He adds, that he has not "yet satisfactorily made out any difference in the characters of the shells of the two supposed sexes. The native divers' opinion, quoted by Capt. Steuart and Mr. Lebeck, viz. that the large flat ones are males, and those that are thick, concave, and vaulted, females," is not borne out by his microscopical observations, as he found well-formed ova in oysters which were broad and flat.

With regard to the fecundation and spawning of the Pearl Oyster, Dr. Kelaart states that from March to June every oyster that he opened, whether young or old, except the few which contained the milky seminal fluid, had ova in the ovaria, so that the Pearl Oyster, like the Common Oyster, is in spawn almost from its birth. From July to September, when the present investigations were brought to a close, the oysters examined did not all contain ova; in some the ovaries were only half full, in others nearly empty. "It will be interesting," as the author observes, "to proceed with these monthly examinations, and to ascertain whether the oyster is only in spawn at certain periods of the year; and, if possible, to determine whether it spawns more than once in twelve months." The ova are pear-shaped, measuring $\frac{3}{1000}$ of an inch in diameter at their widest part, and $\frac{6}{1000}$ of an inch in length. The number of eggs contained in the ovaria of an oyster of five or six years of age are calculated at not less than twelve millions, so that the fecundity of the animal must be exceedingly great.

The foot with the byssus is described by Dr. Kelaart as follows:—

"This important member, which has so many useful services to perform in acephalous mollusks, requires a more than ordinary consideration. It is that long, brown, leech-like member, which is seen when the animal is at rest, coiled up in a corner on the right side, above the byssus, which, when protruding out of the shell, and moving about, gives one the popular idea of a tongue. It is of a dark brown colour above, and whitish beneath; in middle age it is speckled. It is composed of longitudinal and transverse muscular fibres, the latter interlacing between the former, which proceed in two columnar masses from each side of the adductor muscle; between the bundles of fibres are placed the abdominal viscera. From its base is sent off, posteriorly, a glistening white fibrous band; this is attached to the duplicature of the mantle, near the angle of the valves. Thus the foot is seen to be admirably adapted for locomotive powers; and also serves, by its connexion with the adductor muscle, to lengthen or shorten the cable or byssus. The foot, in a full-sized oyster, is about two and a half inches long when extended; at rest, it is not more than one and a half inch in length. It is broad at the base, tapering to a conical point; the upper surface is rounded and smooth, the lower flattened and grooved. The groove extending from the base, terminates at the point in an oval cup-like fosset. This groove is lined by a secreting membrane, and is an exact mould for the formation of the byssus, at the will of the animal. When it finds a necessity for making one, the foot is protruded out of the shell, and with the tip it seeks out a spot where it can rest the terminal disc of the groove. If not satisfied with the substance or position of the stone or any other matter on which it rests, it removes to another more suitable spot; for a few minutes (say five or six, if the animal is strong) it rests, and is then retracted within the shell, leaving behind a strong fibre with an oval disc, of the form of the groove in the foot. This whitish fibre is attached to the base of the foot at one end, and to the rock, or to the shell of another oyster, at the other. In a day or two, this fibre becomes of a bronzed greenish colour, and looks like hair, with a broad flattened oval root attached to the rock. This process is again and again repeated, at intervals of a few minutes, till a sufficiently strong cable is formed. In a large oyster, removed from the sea, upwards of fifty such fibres form a thick strong cable or byssus, which is attached to the base of the foot by a bifurcated fleshy root. The animal cannot detach the byssus from the rock to which it is attached, but it has the power of casting it off its own body and leaving it behind (like a ship letting slip her cable and anchor in a storm, and sailing off to sea), in order to make another byssus, either on the same rock, or on any other convenient place.

"I observed all this process in the aquarium, at a very early period of my investigations; and was not surprised to find, that the Pearl Oyster, having nearly the same organs as the Mussel, should form and reform its byssus. But I was agreeably satisfied in learning by these observations, that Captain Steuart, in his valuable and interesting 'Monograph on the Pearl Fisheries of Ceylon,' was incorrect in denying to the Pearl Oyster this faculty. He states, that '*it is not believed that Pearl Oysters have the power to detach themselves, or to remove at their own will.*' I have not only satisfied myself, and many friends who have seen the oysters in the aquaria which I have established, that the Pearl Oyster can detach or unmoor itself, but likewise that it walks away with its foot foremost, and the shell behind; and does not, as Captain Steuart observes, '*move with its hinges in advance.*' This 'shuffling' movement alone attracted Captain Steuart's attention, but it is an unimportant one; as all bivalves without a byssus have it, and it is independent of the will of the animal, owing to the valves being opened and closed for the purpose of respiration."

"When an Oyster is first put into a vivarium, it sickens, *i. e.*, the mantle becomes retracted, and a collapse is observed;—in a few hours it revives, but, with few exceptions, it is on the third or fourth day that the portion of byssus attached to the foot of the animal is shaken or cast off, and the animal puts out its foot and forms another near the spot where it lies; or walks, by a snail-like motion of its foot, to, or up the side of the glass, to the level of the water, and there fixes itself. Some of the oysters which were thrown into the sea, are now seen growing on the sides of rocks, four and five feet from the bottom."

These observations are conclusive as to the power possessed by the Oyster of reforming its byssus, and the possibility of removing it from the deeper parts of the sea to situations where the fishery may be carried on conveniently; and this appears to have been proposed by Dr. Wright, in a Report prepared about the year 1803, which, however, seems to have been misunderstood. It appears, in fact, from Dr. Kelaart's observations, not only that the Pearl Oyster can reproduce its byssus when it has been torn from its previous resting-place, but that it can even detach itself voluntarily from its moorings and attach itself in another place, and this not once only, but several times, as he has noticed "that some oysters will go through this process a dozen times in less than a month." This power of forming a new byssus is possessed even by the large specimens, although in a less degree than in younger individuals; the latter also possess more locomotive power than those of greater age, and appear to employ it in gratifying their strongly gregarious instincts; for Dr. Kelaart tells us, that when several young oysters are placed in various parts of an aquarium, they will, sooner or later, be found attached to each other; and he adds, that "the older ones have also this desire; but their heavy shells impede their motions, and they are contented to remain apart from their fellows." The formation of a new byssus is sometimes caused also by crabs, shrimps, and other marine animals nibbling through the old one. Dr. Kelaart also states, "that the Pearl Oyster will move about in search of food, if the locality in which it is originally placed is not rich in its natural supplies," and that it will quit its original situation if the water is much agitated or rendered impure by mud, or the decomposition of organic matter, or unfitted for its habitation by a great influx of fresh water. Nevertheless, the mollusk appears to be exceedingly tenacious of life; for it will "live in brackish water, and in places so shallow that it must be exposed for three or four hours daily to the sun and other atmospheric influences."

Taking all these circumstances into account, there seems to be every foundation for the hope expressed by our author, that the Pearl Oysters may be successfully transferred from their native beds, and made to colonize other parts of the sea. His experiments, indeed, appear to be conclusive upon this point. He says:—

"I have successfully established a colony of Pearl Oysters near Fort Frederick, in the open sea, at various depths; and have also oysters which have been living for several months in wooden boxes, finger-glasses, glass globes, chatties, and large canoes, sunk in the sea. Some were thrown into the sea, after being removed from the inner harbour and kept in my house in chatties and tubs for two and three days. The byssus of most of them had been broken and torn from the rock. These they have cast off, and are now living attached to each other, and to pieces of coral, and to rocks, exposed to all the influences of the sea."

Of the general habits of the Pearl Oyster Dr. Kelaart speaks as follows:—

"The whole occupation of the Oyster, when fixed to a spot, appears to be, keeping its valves open and admitting food to its mouth. For several hours the valves remain open, they then close for a few minutes, or for an hour or two, then open again. At night, the valves remain generally open till towards daylight, when they close, and remain so till the sun shines brightly over the horizon. It is during the early part of the night, or soon after sunset, that they exercise, *when required,* their locomotive powers. I have watched the oysters in aquaria for nearly a whole night; and they appear to be then active in moving and attaching themselves to new localities. During the day I have only seen on one occasion an oyster form a new byssus. This nocturnal habit is, doubtless, an instinctive precaution; for should oysters move during the day, they are more likely to become the food of fishes and other animals which prey upon them. Their movements are instinctive, and guided by the sense of touch. Darkness suits them better than daylight, of the difference of which they are very sensitive."

The Tamblegam Pearl Oyster.

It is well known that, besides the true Pearl Oyster, many other species of Mollusca produce perfect pearls, some of which possess considerable lustre. Amongst these is the Common Oyster (*Ostrea edulis,* L.), which sometimes contains good pearls, as in the case referred to by Möbius of a worthy Hamburgher, whose tongue detected the presence, in an oyster which he was on the point of swallowing, of a pearl, for which a jeweller paid him upwards of three pounds (22 dollars). The common *Anodonta cygnea*, L., of our fresh waters, also occasionally contains small pearls; and the European Pearl Mussel (*Unio margaritifer*, L.) is the object of considerable fisheries in some parts of Germany, as it was formerly in our own country. Of other known pearl-bearing Mollusca, Dr. Möbius mentions that the *Pinna nobilis*, L., produces a brown pearl; *Mytilus edulis*, L., a pale-blue one; *Spondylus gæderopus*, L., greenish and pale rose-coloured pearls; *Arca Noæ*, L., a violet, and *Anomia Cepa*, L., a purple pearl. Nearly allied to the latter is the species referred to by Dr. Kelaart as the Tamblegam Pearl Oyster (the *Placuna placenta*, L.), which, like the *Anomia*, belongs to the great family of the *Ostreidæ*. It is found in the salt-water lake of Tamblegam, which is separated by a narrow neck of land from the great harbour of Trincomalee, and although the pearls produced by it (which are of a lead-colour according to Möbius), are not more than one-third of the value of those obtained from the true Pearl Oyster; still, as the number of pearls procured from them per thousand is three times as great as that obtained from the *Meleagrina*, and the shells, according to Dr. Kelaart, are worth *at least* ten shillings per thousand, whilst those of the true Pearl Oyster of Ceylon are of little or no value in consequence of their small size, there seems to be every reason for believing that, with proper management, this pearl-fishery of Tamblegam would constitute an important source of revenue to the Government of Ceylon. This, however, as we shall see, is at present by no means the case.

The Tamblegam Oyster (*Placuna placenta*) is called the 'Vitre Chinoise' by some French writers, and the 'Window Oyster' by English travellers in China, from the circumstance that its semi-transparent shells are used by the Chinese instead of glass in windows. "When full grown, the valves measure, at their broadest transverse diameter, from 6 to 7 inches, and their longest longitudinal diameter is about the same; some, half an inch more." They appear to arrive at maturity in about three years, and to thrive best in brackish water, although they are destroyed by a great influx of fresh water. As in the true Pearl Oyster, the young have ova in their ovaries. The Tamblegam Oyster, "having no byssus, is not attached to any hard substance, nor is it cemented, like some of the edible oysters, by the hinge, or by one of the valves, to any object, but lies either flat on the mud, or is fixed loosely in a semi-vertical position, with the wedge-shaped hinge buried in the mud." From this circumstance, coupled with the exceedingly flattened form of the shells, pearls are very liable to drop out when the animal reaches its full growth; and Dr. Kelaart therefore recommends, "as the best periods for fishing, the time when the animal has closed its supposed two years' age, or when the shell measures from 5½ to 6 inches in transverse diameter."

The fishery in the Tamblegam Lake, as elsewhere, is carried on by divers, and from Dr. Kelaart's statements great injury appears to have been done to the banks, by the granting of a three-years' lease to native renters, without any proper restriction as to the size of the oysters to be fished. One bank, called the Natcha Cooda, is already ruined, unless the Government takes steps to restock it with young oysters; and Dr. Kelaart considers that "there is no prospect of even an average good fishery before the middle of 1859." He says:—

"I watched the number of oysters fished during the two days I was lately at Tamblegam (Keenear), and have to report, that there could not have been less than 30,000 on each day. More than two-thirds of this number were young, and had better have been left in the lake for another year or more. The renter is evidently making the most of the few months he has yet liberty to fish, or *rather ruin the bank*. The Tamblegam Wanniah, and all the divers whom I questioned on the subject, stated, that in the early part of the present year more than 50,000 oysters were fished daily. It is therefore impossible to arrive at any other conclusion, than that the former renters misrepresented the state of their finances, from the Pearl-banks, when they got Government to remit some portion of the rent, and had the fishery re-sold for a smaller sum, to another native,—a relative, I am informed, of one of the original renters.

"All oysters are very prolific, and the *Placuna* is not an exception to the rule; for, at the lowest calculation, in three years there must have been fished from this bank, upwards of 18 millions of oysters, supposing that there were *only* 200 fishing days in each year. The renters' share must have been (allowing five shillings for each thousand oysters) nearly £2250, from which, deducting the three years' rent, viz. £901, they must have derived a profit of at least £1250. To this profit must be added another source of gain (a very ingenious one), from the divers' share of oysters. The diver is allowed half the quantity fished, but he is not permitted *to sell* the oysters at the best market, or to the highest bidder. He is obliged to open the oysters when fresh, and sell to the renter all the pearls, at a fixed rate, which the renter takes good care shall be below the market value. Any plan, therefore, which may relieve the diver of this grievance, will, I am sure, be thankfully welcomed by at least 200 individuals, whose chief means of living is by diving for Pearl Oysters."

Taking these facts into consideration, Dr. Kelaart advises the application of various restrictions to the fishery, the nature of which will suggest themselves readily enough to most naturalists, and at the same time recommends the employment of ordinary oyster-dredges for removing the mollusks from the banks; being unattached, they would of course easily be brought up by the dredge. The small oysters brought up might be returned immediately to the bank, or kept to be transferred to some other suitable locality. By this means he thinks the numerous salt-water lakes of the Ceylonese coast, such as those of Calpentyn, Puttam, Batticaloa and Hambantotte, might easily be stocked with this Pearl Oyster, when they would yield a handsome revenue to the Government. To test the feasibility of this proposition our author has already removed about 1200 middle-sized oysters, obtained from the water of the Tamblegam fishery, to *Yard Cove* in Trincomalee Harbour, where the muddy bottom promises to be suitable for breeding them.

Production and Structure of Pearls.

"There are pearls," says Möbius, "which, like the shells in which they were formed, consist of three different systems of layers,—only that these are superposed in a reversed order. In the shell, the nacreous layer forms the *innermost* coat; in the pearl, on the contrary, it constitutes the shining outer coat; so that the pearl, as it were, only represents a reversed pearly shell, and consequently possesses all the chemical and physical properties of the latter, except those for which it is indebted to its round form." Under these circumstances the qualities of the pearl must necessarily depend to a very great extent upon those of the shell in which it is produced; and the analysis of the nacreous layers of different shells shows a sufficient diversity of composition to account for the different qualities of the pearls produced from them. Thus, according to Schlossberger, the nacreous layer of the Common Oyster contains 94·7–98·2 per cent. of carbonate of lime with only 0·8–2·2 per cent. of nitrogenous organic matter; whilst the same layer in the true Pearl Oyster contains, as found by Ulex, only 87·6 per cent. of carbonate of lime, and the amount of organic matter rises to 11·8 per cent., or more than five times the largest quantity found by Schlossberger in the Common Oyster. The latter also contains 0·8–3·1 per cent. of other earthy salts wanting in the Pearl Oyster, which, however, contains 0·6 per cent. of chloride of sodium. It is to this large amount of organic matter that the true pearls are indebted for their hardness, which is considerably greater than that of crystals of carbonate of lime; and the same cause is doubtless effective in heightening their lustre. The large amount of organic matter contained in them also explains their low specific gravity, which is 2·650–2·686, or 0·1–0·3 less than that of pure calcareous spar or Arragonite.

The *surface* of pearls is not perfectly smooth, but covered with very fine microscopic elevations and depressions. These are more or less irregular in their altitude, but approach most nearly to equality in pearls of the finest water. In pearls which exhibit a certain iridescence, and which, when turned in different directions towards the eye, present even very faint bluish, greenish, and reddish tints, the surface is found to present delicate, irregularly curved furrows, which either run tolerably parallel to each other, or form small, irregular, closed curves. This is due to the mode of growth of the pearl, in which thin layers of nacre of small dimensions have been laid over each other. There is no continuous layer all over the pearl, but a number of small portions, which sometimes overlie the margins of the subjacent layers, and sometimes leave them uncovered*. This structure is seen most distinctly in the pearl shell, where the conditions are rendered more simple by the layers being deposited on a flat or but slightly curved surface. The distance of the furrows from each other is not always the same: sometimes they may be recognized with the simple lens, whilst on other parts they approach within $\frac{1}{3000}$th of an inch of each other. That the iridescence of nacre, or the nacreous colour, as distinguished from pearly lustre, is caused by the interference of the light reflected from these furrows and the intervening edges of the strata, is proved by the circumstance, ascertained by Brewster, that impressions of mother-of-pearl taken in red or black sealing-wax exhibit the same phænomena of colour distinctly. In pearls, in consequence of their spherical form, the different masses of coloured light are so diffused, that they unite to form white light; and this takes place with the greater perfection in proportion as the furrows are lost, and become converted into a surface of fine elevations and depressions.

For their *lustre* pearls are indebted to their being composed of thin layers, which allow light to pass through them, whilst the numerous layers lying one under the other, disperse and reflect the light in such a manner that it returns and mixes with that which is directly thrown back from the outer surface. It is the cooperation of light reflected from the surface with light dispersed and reflected in the interior, that gives rise to lustre; for this reason the knots of window-glass exhibit pearly lustre, and the membranes of pearls deprived of their lime are almost as lustrous as solid pearls, except that their whiteness is destroyed. "The two masses of light entering the eye, act upon it from different distances. Now as it adapts itself to the body seen through the transparent layer, it cannot distinctly see the light reflected from the surface, and the consciousness of this infinitely perceptible reflexion produces the phænomenon of lustre" *. The thinner and more transparent the layers of which the pearl consists, the more beautiful is its lustre, and in this respect the sea-pearls excel those of our river-mollusks.

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* "This discovery of the stratification solves the contradiction between Brewster's and Carpenter's representations of the matter." (Möbius.)

Besides the furrows on the natural or cut surfaces of mother-of-pearl, fine sections or laminæ of cleavage exhibit a second system of *fine dark lines.* These, however, are never so distinct as the superficial furrows, but always appear somewhat cloudy and very finely undulated. In several specimens in the possession of Dr. Möbius they follow the same direction, whilst that of the superficial furrows varies frequently; so that the two systems are sometimes parallel and sometimes intersect each other at all angles. These minute lines also remain at the same distance apart ($\frac{1}{7700}$th of an inch, according to Herschel †). This structure of the nacreous layers is probably of great importance in the dispersion of the light which is reflected by mother-of-pearl.

In pearls these fine dark lines usually run round the globe in the direction of circles passing through its poles. Sometimes, however, they run in very various directions, and in a pearl from *Unio margaritifer* from which Dr. Möbius had dissolved the carbonate of lime by acetic acid, the lines of the different strata of membrane crossed each other at various angles.

In thin sections of pearls a quantity of fine lines run round the central point in the layer of nacre, but these rarely form closed curves, most of them losing themselves again without completing the circuit, and thus showing, like the superficial furrows, that the pearl does not grow by complete spherical coats, but by the superposition of small segments. Sometimes layers occur which run almost all round, and show that they were formed at one time, by their uniformly darker colour. These concentric lines of the nacre are intersected by two systems of extremely fine lines at angles of about 10–15°, whilst the latter intersect each other at angles of about 20–30°. These lines appear to be due to an intimate structure of the nacreous layer, probably to the unequal inclination of its particles towards the cut surface. When a portion of the layers are cut at an acute angle, transitions are seen to take place from the superficial furrows to these lines. It is also probable that the above-described fine dark lines of the nacreous layers take part in their formation, and especially in giving them their finely punctured appearance when cut transversely.

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* Dove, Farbenlehre und optische Studien, p. 117.

† Edinburgh Phil. Journ. ii. p. 114, 1820.

In one section from a sea-pearl of good lustre, the nacreous layers are penetrated almost all round by dark ramifications arranged radially. These have also been found by Carpenter in many shells; as they do not disappear with the carbonate of lime, he regards them as walled (*ausgekleidete*) canals.

The finest pearls usually consist only of nacreous layers surrounding a nucleus. To this their white colour is due, as a large dark nucleus shines through the layers, and renders them dull. The grey tint of the so-called immature pearls is due to *columnar cells,* identical with those of the middle layer of the shells, which extend radially from the nucleus to the nacreous layers. In transverse section these appear as three- or six-sided cells with straight or curved outlines, and they either retain the same diameter throughout, or have their extremities pointed and wedged in between each other. When the lime is removed by acetic acid, they remain as hollow columns, with brownish membranous walls. In the midst of them there often rises a membranous plate, which looks like a cell-nucleus, and which is attached to a delicate membrane situated between the columnar and nacreous layers. The membranous walls of the columnar cells are either transversely striated, or furnished with transverse rows of pores; and in one case the pores and striæ occur together in the same column. Carpenter regards these columns as consisting of flat cells laid one upon the other, and we may suppose that the fusion of these takes place in the same way as in the formation of the vessels of plants. This view has certainly more in its favour than that of Heinrich Meckel*, who supposes that the columnar layer is produced from the nacre in the same way as Réaumur's porcelain from amorphous glass.

In many pearls the inner extremity of the columns rests upon a brownish-yellow mass which encloses the nucleus. It is usually homogeneous, rarely stratified, and possesses all the properties of the epidermis of the shells. This leads us to the consideration of the formation of pearls and its causes, upon which so many theories have been propounded.

According to the ancient Indian notion adopted by Pliny, and after him by many others, the mollusk is incited to the production of pearls by the falling of drops of dew into its gaping valves; and so firmly had this idea taken possession of the human mind, that Columbus, on discovering the coast of Paria, thought he had fallen upon the right place for pearls,—the trees grew with their roots in the sea, and these very roots were covered with oysters, ready to receive any quantity of dew-drops that might fall from the leaves above them. But the oysters unfortunately were of the wrong sort. Ælian's theory was, that pearls were produced by lightning flashing into the open shells; and it was not until many years later that a less poetical race of naturalists adopted more material hypotheses, and attributed to pearls a similar origin to that of the gall-stones, urinary calculi, Bezoar-stones, and other concretions found in the higher animals. According to another view, pearls were the eggs of the mollusks; and Dr. Möbius quotes from Valentini a statement that, in the year 1700, "a Swedish major and a Livonian nobleman saw a shell-fish creep out of a pearl which a fisherman had laid before them on the table." In 1717 Réaumur showed that the structure of pearls was identical with that of the shells producing them, and that those of the *Pinna* of the harbour of Toulon consisted either of nacre, or of a system of columns, according to the place in which they were formed.

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* Mikrogeologie, p. 26, 1856.

Under any circumstances, however, the production of pearls can hardly occur in the natural course of the secretion of the materials of the shells, and they must be regarded as abnormal deposits of this material, the impulse to which must be given by some peculiar cause. Réaumur ascribes the formation of pearls to a morbid effusion of the coagulating shell material, and Dr. Möbius considers that this may sometimes be the case with those pearls which have a crystalline calcareous nucleus. But these appear to be few in number, and it seems now to be a settled point that, at all events in most cases, the formation of pearls is caused by the intrusion of foreign bodies between the mantle of the animal and its shell. By the majority of writers grains of sand are described as the most frequent irritants, and Dr. Kelaart appears to admit their intrusion as one of the causes of pearl formation*; but, on the other hand, Dr. Möbius states, that of 44 sea-pearls (from America and the East Indies) and 15 freshwater pearls, of which he has prepared sections, not one presented a sand-grain as its nucleus. A few, as already stated, contained a "radiately fibrous, crystalline calcareous nucleus," but in the majority the nuclei were of an *organic nature*.

With regard to the origin of these organic nuclei, two theories have been put forward. According to the earliest of these hypotheses, set up by Sir Everard Home in 1826†, the ova of the mollusks form the nuclei of pearls; and in support of this view the author stated that he had found pearls in the ovary, and adduces two letters from C. Sandius, dated in 1673 and 1674, and published in the 'Philosophical Transactions' for the latter year, in which the same opinion is expressed. This theory of Sir Everard Home's was contradicted by Von Baer, in a paper published in Meckel's 'Archiv' as early as 1830; and it appears to be untenable as regards the formation of pearls from abortive ova *in the ovaries*, but a modification of it is brought forward with great appearance of probability by Dr. Kelaart, who says, "that the ova which escape through the distended coats of an overgrown ovarium, and are imbedded in the interstices of the mantle, become nuclei of pearls formed in this situation." In support of this view he states that he has "repeatedly examined seed, or young pearls, in process of formation; and with a magnifying power of $\frac{1}{5}$-inch lens, was able to see distinctly the outlines of two or three ova through the first or superficial layer of nacre, surrounded by groups of ova. It can be readily understood how an overcharged ovarium will, by some accident or spontaneous evolution, have its coats ruptured, allowing the ova to escape and become inserted in the contiguous attenuated parts of the mantle. As pearls are more usually found imbedded in the mantle near the hinge, the most likely place where the ovarium is liable to rupture, I consider this very conclusive of the new theory I have here proposed*."

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* See p. 83.

† Phil. Trans. 1826, p. 338.

(Dr. Kelaart also thinks it possible that the siliceous skeletons of the Diatomaceæ, which constitute a great part of the food of the Pearl Oyster, may sometimes, by escaping through the coats of the stomach or otherwise, get into the interstices of the mantle, and there give rise to the production of pearls. He adduces no positive observations in confirmation of this opinion, except that he once, in examining "seedling" pearls, found a *Navicula* amongst the [escaped?] ova.)

The second modern theory above alluded to is founded upon the observation of the fresh-water pearl-bearing Mollusks (*Anodontæ* and *Uniones*), and attributes the formation of pearls to the intrusion of parasites into the mantle. Filippi† found in some ponds in the park of Racconigi, near Turin, individuals of the common fresh-water Mussel (*Anodonta cygnea*), the mantles of which contained sacs with larvæ of *Distoma duplicatum*, Von Baer, and at the same time saw "a corresponding quantity of pearly asperities, of various forms and development, passing through all possible degrees to real, shining, nearly spherical pearls, scattered over the adjacent surface of the shell." On carefully removing the pearly concretions which appeared to be youngest, and examining them with the microscope, he always detected in them the remains of *Distomata* (*Cercariæ*), which had served as the nucleus for the calcareous matter. Even in free pearls he found an organic nucleus (consisting of portions of *Echinostomum* and *Limnochares Anodontæ*), although he never found any animal that could be determined with perfect certainty. From these observations Filippi concludes that the production of pearls is intimately connected with the presence of parasites, and that the want of the latter may be the cause of the non-formation of pearls in some localities. He denies that pearls are the result of disease, and that their nuclei are ever formed by grains of sand.

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* It would appear, however, that Dr. Kelaart thinks it possible that an over-distended ovarium is one of the causes of pearls being discharged from the oyster and lost. He adds: "If this be really the case, it will easily account for the singular fact, that a sample of oysters, fished in the month of October, will yield a larger proportion of pearls than a batch of oysters fished from the same bank in the months of April and May of the following year."

† *Sull' Origine delle Perle*, translated with notes by Dr. Küchenmeister, Müller's Archiv, 1856, p. 251; and *Encore un mot sur la formation des perles*, Müller's Archiv, 1856, p. 490.

Küchenmeister*, following up the ideas of Filippi, and admitting that pearls may be produced by the intrusion of *Distoma*-larvæ and other Entozoa into the mantle, maintains that the principal impulse to the formation of pearls, at all events in the Saxon river Elster, is given by the water-mite *Limnochares Anodontæ*. The eggs of this mite are deposited in the fresh-water mussels, and enveloped by the latter in cysts, from which, however, the six-legged young can usually escape with ease. After swimming about for some time, and attaining their full growth as larvæ, these hexapod mites return into the mollusk, and become again enclosed in a capsule, within which they change their skin and acquire their perfect form. Thus the natural habits of this mite give rise to the formation of numerous spherical cysts, which may remain in the mantle of the mollusk even after the escape of their inmates, and thus furnish the most favourable conditions for the production of rounded pearls. The mites prefer still water, and it is in situations where this condition is fulfilled that the greatest number of pearls are found.

Küchenmeister's observations induced Von Hessling to investigate this interesting subject in the Bavarian waters, and the results of his researches were published in the *Gelehrten Anzeigen* of Munich (1856). In adherent pearly asperities of the inner surface of the shells of fresh-water mussels he found "partly true sand-grains, or minute particles of fine mud, in which the animals live; partly remains of Algæ with distinctly recognizable conjugations, the individual cellular segments of which are still incrusted; partly eggs in the most various stages of development and decomposition; and partly parasitic animals in the most various stages of development." He only found one *Di-*

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* Müller's Archiv, 1856, p. 269.

stoma-nucleus in many hundred small free pearls from the freshwater mussels, and in "about 40,000 specimens of *Unio margaritifer*, opened partly by Von Hessling and partly by the fishermen, no trace of a parasite or of an egg could be found." No traces of eggs or parasites were detected in hundreds of oriental, Scotch, and Bavarian pearls, which he opened with chisel and saw, and treated with organic and inorganic acids.

Dr. Möbius, however, has arrived at a directly opposite result, by following a rather more cautious method of investigation, and grinding down the pearls with a fine file and stone. His results are therefore far more to be depended upon than those of Von Hessling, who seems to have carried on his researches in rather too wholesale a manner. In eight pearls from the west coast of America he found remains of Entozoa forming the nucleus, and one of those figured in his plate is evidently a Trematode larva. In other curious specimens the nucleus is covered with layers of epidermis, which appear to have been drawn asunder by the movements of the living nucleus. As a general rule, the organic nucleus seems to shrink more or less after its enclosure, and the space thus left is usually filled up in part by crystalline fibres, probably consisting of carbonate of lime infiltrated through the first layers. The pearls already referred to as containing a nucleus of crystalline carbonate of lime are also probably caused originally by the access of young parasites, which, retaining their vitality, subsequently break through the first layers of the pearl, and thus leave a hollow space in its centre. The great weight of evidence, therefore, is in favour of the organic origin of the nuclei of pearls, partly from the eggs and encysted young of parasitic animals, and partly, according to Kelaart, from the escape of the eggs into the interstices of the mantle, on the accidental rupture of an overcharged ovary. Dr. Kelaart and Von Hessling also admit the intrusion from without of foreign inorganic matters as one of the causes of pearl-formation; and the former states that the oysters, when removed into an aquarium, retract their mantle considerably, and retain it in this condition even for some days,—a condition which would be very favourable to the access of extraneous matters to the interstices between the mantle and the shell. It is quite possible that a similar condition may prevail amongst the Pearl Oysters residing in the open sea, for Dr. Kelaart says, "Most of the oysters in which I have found pearls had external marks of having been retarded in their lateral growth, and displaced in early life from their fixed position on a bank. I am inclined to believe that oysters which have abundance of food, and are not disturbed, remain fixed for the last two or three years of their growth to one spot. These are less likely to have a large proportion of pearl-bearing individuals among them. This, of course, requires more extensive practical observation, either on the beds in the harbour of Trincomalie, or on the pearl-banks of Arripo."

Under any circumstances, this retraction and extrusion of the mantle must be of considerable importance in determining the internal structure of the pearls; for as the different layers of the shell (epidermis, columnar layer, and nacre) are secreted by different parts of the surface of the mantle, the pearls which contain more than one of these substances must have been in contact successively with the corresponding regions of the mantle. Thus if a pearl be originally formed at the edge of the mantle (which will be the case when dead extraneous matters get within the shell, whilst the mantle is retracted as above described), the nucleus will be immediately surrounded by a layer of epidermis; and if it be subsequently passed *inwards* (by the extrusion of the mantle or otherwise) through the columnar region to that which secretes the nacreous layer, it will exhibit the three layers in the same order as in the shell. The finest pearls are those formed entirely in the nacre-secreting portion of the mantle; but if those originally produced in this situation be passed *outwards* (by the retraction of the mantle or otherwise), they will acquire a columnar, and even an epidermic, layer; and by passing inwards again, these may be in their turn coated with nacre. Instances of the structures thus produced appear not to be uncommon, and several of them are described and figured by Dr. Möbius. Pearls found imbedded in the tissues of the body at a distance from the mantle, are probably carried to their resting-place by the circulation.

Ever since the admission of the fact that the formation of pearls is caused by the intrusion of foreign bodies between the mantle of the mollusks and their shell, attempts have been made to produce similar effects by artificial means. In 1761 Linnæus announced to the King and Diet of Sweden that he could compel mollusks to produce pearls, at the same time offering to publish his method for the benefit of the State. He seems, however, to have thought better of the matter, and sold his secret for 500 ducats to one Bagge, a merchant of Gothenburg, whose heirs offered it for sale again in 1780. Beckmann, who narrates this, says: "Linné once showed me in his collection a tray of pearls, and said, 'Hos unionis confeci artificio meo; sunt tantum quinque annorum, et tamen tam magni.'" Beckmann adds,—"I believe that Linné had described his art as early as 1746 in one of his works, before he had the idea of making use of it as a mystery. I refer to a line in the sixth edition of the 'Systema Naturæ,' at p. 195, which runs,—'Margarita, testæ excrescentia latere interiore, dum exterius latus perforatur.'* I once told him that I had discovered his secret in his own writings; he seemed to be embarrassed, made no inquiry as to the passage to which I referred, and broke off the conversation." There is no doubt that attached half-pearls may be produced, when the shell is bored through by a worm, or artificially. These hemispherical pearls are often of large size; Dr. Möbius describes three of nearly half an inch in diameter.

Imperfect pearls are usually produced artifically by inserting foreign substances between the mantle and the shell. The Chinese appear to be the principal operators in this way. According to Grill they insert a string of 5 or 6 spherules of mother-of-pearl into Mussels in a lake near Canton, by which they are covered with a nacreous layer in the course of a year. These pearls are used for embroidery, in which their defects may be concealed. The Chinese also produce hemispherical pearls upon the inner surface of the shells of *Barbata plicata* (*Dipsas plicatus,* Leach), by inserting mother-of-pearl forms between the shell and mantle, and specimens of this shell are not uncommon, bearing numerous attached pearly figures of Chinese deities, formed upon metal moulds in the same situation. Dr. Gray also says that the Chinese produce nearly globular pearls in this mollusk, around silver wire.

Dr. Kelaart states that he has "doctored" some Pearl Oysters "according to the plan adopted by the Chinese, in the case of the large fresh-water Mussel," but does not describe the particular process employed by him. At the end of the copy of his Report which he has had the kindness to forward to us, he has, however, appended a manuscript note, dated the 7th December, 1857, in the following words:—"Since writing the above, I have established the fact, that good pearls can be made by the oysters which are treated as the Chinese treat the fresh-water Mussel. If the Ceylon Government will not establish artificial Pearl-banks, other Governments may try the experiment, and the Arripo bank be in time valueless."

X.—*On the Structure and Affinities of* Myricaceæ, Plataneæ, Altingiaceæ *and* Chloranthaceæ. By B. Clarke, Esq., F.L.S. &c.

[With a Plate.]

MYRICACEÆ.

The ovary of this family having engaged the attention of some most accurate observers, by whom it is regarded as simple, the following remarks on its structure may prove interesting, especially as the stigmas, which are ordinarily two, are occasionally

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* This passage is suppressed in the tenth edition.